Phytoliths, parasites, fibers, and feathers from dental calculus and sediment from Iron Age Luistari cemetery, Finland

Juhola, Tytti

2019-10-15

Juhola , T , Henry , A G , Kirkinen , T , Laakkonen , J & Väliranta , M 2019 , ' Phytoliths, parasites, fibers, and feathers from dental calculus and sediment from Iron Age Luistari cemetery, Finland ' , Quaternary Science Reviews , vol. 222 , 105888 . https://doi.org/10.1016/j.quascirev.2019.1058

http://hdl.handle.net/10138/305570
https://doi.org/10.1016/j.quascirev.2019.105888

Quaternary Science Reviews 222 (2019) 105888

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Phytoliths, parasites, fibers, and feathers from dental calculus and sediment from Iron Age Luistari cemetery, Finland

Tytti Juhola [a, *], Amanda G. Henry [b], Tuija Kirkinen [a], Juha Laakkonen [c], Minna Väliranta [d]

[a] Department of Cultures, University of Helsinki, 00014, Helsinki, Finland
[b] Faculty of Archaeology, Leiden University, Leiden, the Netherlands
[c] Faculty of Veterinary Medicine, University of Helsinki, 00014, Helsinki, Finland
[d] Environmental Change Research Unit, Ecosystems and Environment Research Programme, University of Helsinki, 00014, Helsinki, Finland

ARTICLE INFO

Article history:
Received 3 July 2019
Received in revised form
14 August 2019
Accepted 16 August 2019
Available online xxx

Keywords:
Anthropocene
Scandinavia
Micropaleontology-others
Dental calculus
Phytoliths
Parasites
Animal fibers
Bast fibers
Feathers
Iron age

ABSTRACT

Our understanding of subsistence strategies, resources and lifeways of Finnish Iron Age populations remains incomplete despite archaeological, osteological, macrobotanical, and palynological investigations. This is due in part to poor preservation of organic macroremains in the acidic boreal sediments. To address this problem, here we present the first data from microscopic remains preserved in prehistoric dental calculus from Finland. We extracted and analysed both plant and animal microremains from human calculus and burial site sediment samples, originating from Luistari cemetery in southwestern Finland (samples from c. 600–1200 calAD). We recovered phytoliths, parasites, fibers and feathers. While in Finland few previous archaeological studies have investigated phytoliths, our study confirms the importance of these microremains for interpretating dietary patterns. It is also the first time that intestinal parasites have been reported in Finland.

Our study demonstrates that, especially when working with acidic sediments typical for boreal environments, microremain studies can considerably increase the information value of archaeological samples, and that dental calculus and phytolith analysis are important new methods in the research of prehistorical lifestyles. This combined microremain analysis should be more broadly applied in contexts where other dietary records do not remain.

1. Introduction

In boreal environments, the archaeological analyses of plant and animal remains are often challenged by acidic sediment conditions, which promote rapid decomposition of calcium-containing organic matter (Lempiäinen, 2002; Riikonen, 2011). This limits the reconstruction of local behaviors of time periods for which we have no written documents. One such example is the Luistari Iron Age cemetery in Western Finland. While sites elsewhere in Scandinavia, which are located on limestone bedrock, have abundant macroremain records (Larsson, 2015), in Finland there is only limited information on the diet, subsistence, and resources of Iron Age populations. Although graves from this period have been intensively studied, most analyses report limited finds (Aalto, 1997; Lempiäinen, 2002, 2005; 2009; Lempiäinen-Avci et al., 2017; Vanhanen, 2012). Studies of the Luistari graves using traditional macrobotanical approaches have reported sparse finds of weeds and cereals, despite the antimicrobial and preservative effect of metal oxides originating from the numerous pieces of bronze jewellery (Lehtosalo-Hilander, 1982a, 2000; Lempiäinen, 2002; Riikonen, 2011). Only a small number of animal bones have been studied and reported, and these are mainly teeth due to their better preservation (Lehtosalo-Hilander, 1982a:309–310). Microremains have almost never been studied from Finnish Iron Age sites, the only exception being pollen analysis of a handful of grave sediments (Lempiäinen-Avci et al., 2017:132; Tranberg, 2018; U. Moilanen, personal communication 8 March 2019). Despite their rarity, these pollen studies have provided new information on burial practices and plants used for grave furnishing or decorations (Lempiäinen-Avci et al., 2017).

Many studies show that a multiproxy approach that combines microfossil analysis with traditional approaches should become a norm for archaeological analyses (García-Granero et al., 2015; Namdar et al., 2011). This approach would improve the quality of

* Corresponding author.
E-mail address: tytti.juhola@helsinki.fi (T. Juhola).

https://doi.org/10.1016/j.quascirev.2019.105888

grave studies and yield a more comprehensive overview of past environments, cultures, health, and behavioral practices, particularly for acid-sediment sites, such as described below.

1.1. Calculus as a microremain repository

Previous studies have indicated the potential for dental calculus as a source of dietary and other behavioral data. This mineral matrix forms during the lifetime of the individual, and traps informative microremains such as starch grains and phytoliths (e.g. Cummings et al., 2018; Hardy et al., 2012; Henry and Piperno, 2008; Henry et al., 2011, 2014; Lalueza Fox et al., 1996; Mariotti Lippi et al., 2017; Power et al., 2018; Tromp et al., 2017; Warinner et al., 2014), charcoal particles (Hardy et al., 2016), mineral fragments (Radini et al., 2019) and fern sporangia (Fiorin et al., 2019).

1.2. Microremains

Phytoliths are microscopic silicon dioxide formations, formed in various plant tissues (Ball et al., 2009; Pearsall, 2015:254; Piperno, 1988, 1991, 2006). Due to their unique morphologies, some phytoliths can be taxonomically identified to genus- or species-level (Ball et al., 2009; Madella et al., 2005; Pearsall, 2015:254; Rosen, 1992). They have been regularly used to provide information about plant use in the past, in part because they preserve well in acidic environments (Cabanes et al., 2009, 2012; Pearsall, 2015:27; Piperno, 2006:1). However, in Finland the tradition waned after the pioneering work by Irmeli Vuorela (Lempiäinen and Vuorela, 1994; Vuorela, 1994a, 1994b; 1999, 2003; Vuorela and Lempiäinen, 1993; Vuorela et al., 1996).

The eggs of intestinal parasites, (e.g. whipworms, pinworms, tapeworms, and roundworms) have been found in a variety of archaeological contexts, reflecting diet, health, and density of human and livestock populations (Bouchet et al., 2003; Cleeland et al., 2013; Dittmar and Teegen, 2003; Fugassa et al., 2008; Hald et al., 2018; Pichler et al., 2014; Søe et al., 2015, 2018). Parasites are passed from an individual to another under unhygienic conditions, but humans can also become hosts of animal parasites (Reinhard, 1992). Parasite remains have never been reported from Finnish sites.

Fibers, including animal hairs and plant materials, reflect the production and use of cloth and furs. Woollen textiles have been reported from the Luistari graves (Lehtosalo-Hilander, 2001). However, textiles made of plant fibers usually decompose in boreal acidic sediments, and the few fibers from Luistari that may be of plant origin, remain ambiguous (Riikonen, 2011).

Some animal furs were identified in Luistari graves. These came mostly from wild animals: European elk (*Alces alces* L.) or reindeer (*Rangifer tarandus* L.), brown bear (*Ursus arctos* L.), grey wolf (*Canis lupus* L.), lynx (*Lynx lynx* L.), European beaver (*Castor fiber* L.), and red fox (*Vulpes Vulpes* L.), though there were also remains of domestic species (Bovidae) (Kirkinen, 2015; Lehtosalo-Hilander, 1982c:68). Furs were used for clothing, wrapping of the bodies, and as material for equipment (Kirkinen, 2015, 2017; 2019; Lehtosalo-Hilander, 1982b, 2000:197).

Bird feather finds are rare in Finnish archaeology, but for the Luistari site some single feathers have been found from grave 390 (Kirkinen, 2015). Feathers have been discovered in several Scandinavian Viking Age graves (Rast-Eicher, 2016:291).

1.3. Study site

Luistari cemetery is situated in Eura, southwestern Finland, and was in operation between 500 and 1500 calAD, and excavated in 1968–1992 (Lehtosalo-Hilander, 1982a, 1982b; 1982c, 2000). Most of the 1300 inhumation, i.e. non-cremated, burials date to the Late Iron Age (800–1200 calAD). Because of its size and richness, the cemetery is one of the most significant Iron Age sites in Finland. The Luistari archaeological collection can be considered as historically and culturally very valuable and unique, therefore we used multi-proxy microremain methods to maximize the recovered information.

We analysed Iron Age inhumation burials by applying an extensive set of microfossil analyses on human dental calculus samples, supplemented by microfossil analyses of sediment samples derived from the graves, and residues on grave items. We discovered multiple types of microremains: phytoliths, intestinal parasites, animal and plant fibers, and feathers. Our data confirms that grains from grasses were eaten in the Late Iron Age, and suggests that the community suffered from poor hygiene, which enabled the spread of intestinal parasites. Moreover, our results suggest that bast fibers were eaten and processed, and that domesticated and wild animal furs and feathers were processed, and support a previously published suggestion that feather-filled pillows were used in the graves.

2. Materials and methods

2.1. Collection of samples

The Luistari specimen collections are archived by the Finnish National Board of Antiquities, and we selected samples from fifteen of the graves. Our samples consisted of 32 dental calculus samples, eight small sediment samples from the graves, five carbonized residue samples, and seven sediment samples that had been classified as unidentified organic matter (here called organic residue samples). In addition, possible residue particles (here called “dirt”) on the surface of 14 items were sampled (See Tables 1 and 2). Two pieces of birch bark were collected from graves 56 and 345 for radiocarbon dating (See Table A1).

2.2. Sampling and preparation procedures

Microscopic particles are readily transported even long distances, and a risk that archaeological samples might be contaminated by modern particles has to be acknowledged (Crowther et al., 2014). Therefore, to prevent contamination, we followed the cleaning procedures used in the HARVEST laboratories, at Leiden University (as described in Power et al. (2018)). We prepared the calculus samples following the recommendations by Warinner et al. (2014) and Tromp et al. (2017), and sampled items with sterile water, following Li et al. (2013), Pearsall et al. (2004), and Perry (2004). The carbonized material was prepared modifying Zarrillo et al. (2008). The sediment samples and samples from organic substances were prepared using sediment preparation protocol of the HARVEST laboratories.

See full process descriptions in Appendix A.

2.3. Analysis

The analysis was performed with transmitted light and polarised microscopy, using a Leica DM 2000 LED microscope with 400X magnification.

The phytoliths were analysed using typological and morphological analysis, following Ball et al. (1996, 1999, 2009, 2016), Rosen (1992), and Out et al. (2016).

The intestinal parasites were identified by their morphology, such as the shape of the eggs, the type of outer membrane, the structures within the oocysts, as well as size, following Cruz et al. (2012), Kreier and Baker (1987), and Fugassa et al. (2008).

Table 1
Dental calculus samples. Tooth identifications Salo (2005). Sex and age according to Lehtosalo-Hilander (1982a, 1982b, 2000). (*) = Female according to Salo (2005).

Catalogue number (NM)	Grave	Sex	Subnumber (Fdi number/M Molar/PM Premolar)	Number of samples	Location (Distal, Mesial, Lingual, Buccal, Not known)	Age approx. (cal AD)	Calculus weight (mg)
18000:1776	56	F	2(PM)	1	N	See Table A.1	0.9
18000:1943	73	F	5(Fdi 26)	2 (a and b)	a B, b M	800–880	a 0.6, b < 0.1
18000:3234	283	M	2(Fdi 15)	1	N	880–950	<0.1
18000:3234	283	M	3(Fdi 16)	1	B-D	880–950	0.5
18000:3307	289	M	2(Fdi 47)	1	B	880–950	<0.1
18000:3307	289	M	4 (M)	1	N	880–950	<0.1
18000:3504	303	M(*)	4(Fdi 25)	1	D	880–950	0.2
18000:3504	303	M(*)	11(Fdi 36)	1	B	880–950	<0.1
18000:3627	320	M	1(M)	1	L	880–950	<0.1
18000:3627	320	M	(M), 2 fragments	2 (a and b)	N	880–950	a 0.9, b 0.3
18000:3640	323	M	4(Fdi 25)	1	M	880–950	0.8
18000:3640	323	M	14(Fdi 37), fragment	1	N	880–950	<0.1
18000:3679	324	F	4(PM)	1	N	880–950	<0.1
18000:3714	325	M	17	1	N	880–950	0.6
18000:3862	346	F	4(Fdi 36)	1	D	600–800	0.7
18000:3862	346	F	6(Fdi 14/15)	1	B	600–800	<0.1
18000:3862	346	F	fragment	1	N	600–800	1.5
18000:3946	348	M	6(Fdi 17/18)	1	B	880–950	0.3
18000:4013	352	F	1(Fdi 45)	1	L	600–800	0.7
18000:4013	352	F	3(Fdi 47)	1	M	600–800	<0.1
18000:4014	352	F	4(Fdi 17)	1	M	600–800	<0.1
18000:4014	352	F	10(Fdi 35)	1	M	600–800	<0.1
18000:4014	352	F	12(Fdi 37)	1	B	600–800	3.3
18000:4439	390	F	2(Fdi 38)	1	D	880–950	0.5
18000:4440	390	F	1(Fdi 11), 2 fragm.	2 (a and b)	N	880–950	a 8.3, b 4.5
27717:29	1260	F	C (Fdi 43), 2 fragm.	2 (a and b)	N	800–900	a 0.9, b < 0.1
27717:29	1260	F	C (Fdi 47), fragm.	1	N	800–900	<0.1
27717:29	1260	F	G (Fdi 44)	1	N	800–900	0.9

Table 2
Other samples. Type of sample: O = organic residue, C = carbonized residue, D = dirt from the surface of item, S = sediment sample. None of the samples were taken from textiles.

Catalogue number (NM)	Grave	Location of residue	Type (O/C/D/S)	Sample size (ml)
18000:1644	56	Under a coin	O	0.072
18000:1647	56	On top of silver pendants	O	0.009
18000:1750	56	Next to textile and fur	C	0.001
18000:1770	56	Inner surface of a ceramic	D	<0.001
18000:1771	56	Small ceramic rim piece	D	<0.001
18000:1772	56	Inner surface of the smallest ceramic	D	<0.001
18000:1774	56	Smaller piece of flint from infilling of the grave	D	<0.001
18000:1779	56	Leg area	S	0.167
18000:1780	56	No data about the context	O	<0.001
18000:3838	345	Next to pieces of bell-buttons	O	<0.001
18000:3839	345	Piece of flint	D	<0.001
18000:3845	345	Next to a bronze cauldron	C	0.0467
18000:3846	345	Outer surface of the cauldron	C	0.037
18000:3847	345	Inner surface of the cauldron	C	0.024
18000:3848	345	Next to the cauldron	O	0.025
18000:3850	345	Under the cauldron	S	0.036
18000:3855	345	Inner surface of smaller ceramic	D	<0.001
18000:3863	346	Inner surface of ceramic	D	<0.001
18000:3864	346	Piece of flint from the infilling of the grave	D	<0.001
18000:3947	348	The bottom of the grave	S	0.125
18000:3963	348	Charred piece of bone from the infilling of the grave	D	<0.001
18000:3964	348	Inner surface of the largest ceramic rim piece from the infilling of the grave	D	<0.001
18000:3964	348	Next to ceramics in the infilling of the grave	S	0.004
18000:4426	390	Next to pearls	O	<0.001
18000:4429	390	Next to bronze ornaments	O	<0.001
18000:4443	390	Inner surface of the largest ceramic piece from the infilling of the grave	D	<0.001
27177:21b	1260	Next to a spiral ring	S	0.500
27177:24b	1260	Under and above the spiral bracelet	S	0.330
27177:29 h	1260	Head area	S	0.330
27177:36	1260	Under a sheath	S	0.125
27177:37	1260	Larger ceramic rim piece	D	<0.001
27177:38	1260	Smaller ceramic rim piece	D	<0.001
27177:38	1260	Ceramic	C	<0.001
27177:40	1260	Inner surface of a large ceramic	D	<0.001

The morphological identification of animal hairs was based on the diameter of the hair and on the structures of medulla and cuticular scales (e.g. Chernova, 2002; Goodway, 1987; Tridico, 2005). The classifications followed Teerink (2003) and Rast-Eicher (2016), and the identification keys on Appleyard (1978), Teerink (2003), and Rast-Eicher (2016) were applied. The classification and identification of bird feathers was based on Brom (1991) and Dove and Koch (2010). In addition, samples were compared with a reference collection of Fennoscandian wild animal species and North European domestic breeds.

The bast fibers were identified by their nodes, transverse markings, and diameter after Rast-Eicher (2016:80–112).

3. Results and discussion

3.1. Phytoliths

In sediment sample 27177:24b of grave 1260 we observed a multicell phytolith, composed of dendritic long cell phytoliths and one short cell rondel phytolith in anatomical connection (See Fig. 1 and Table A2); confirmed by Dan Cabanes, Rutgers University (personal communication 5 Dec. 2018). These two phytolith types are diagnostic of the inflorescences of C_3 grasses (Ball et al., 1999, 2009; Out et al., 2016; Portillo et al., 2006; Rosen, 1992), including wheat (*Triticum* sp. L.) and barley (*Hordeum* sp. L.) (Ball et al., 2009). There is little information on phytoliths from Finnish native grasses, which limits our ability to identify the taxa that our phytoliths represent. We did compare the shape of the dentritic long cells to those from *Triticum* and *Hordeum*, which have species-specific morphologies. Following the measurement protocols by Ball et al. (1999, 2016) and Out et al. (2016:39–40), we were able to measure the widths of six dendritic long cells from the multicellular structure. In Table A2 our measurements are compared with *Triticum* and *Hordeum* measurements reported in Ball et al. (1999) and Rosen (1992), and our phytolith widths seem to be closer to the mean values of *Hordeum vulgare* L. than to those of *Triticum* species. We acknowledge six measurements do not enable statistically confident identification. A more extensive set of measurements and comparable morphometric measurements for rye (*Secale cereale* L.) and native wild grasses should be produced to enable more reliable identification.

Nonetheless, this multicell phytolith represents an important find in the context of the Luistari site and Finnish archaeology in general. This is the first time in Finnish archaeology that these types of species-indicative multicellular phytolith structures were found. Furthermore, this sediment sample was collected from around a bronze bracelet, which was located on an arm that was bent over the middle part of the body. Thus it is possible that the phytolith structure actually originates from the alimentary canal. A single grass seed from a domesticated cereal, unidentified to species, has been reported from a clay pot excavated from this same grave, supporting the dietary use of cereals at this site (Lehtosalo-Hilander, 2000).

3.2. Intestinal parasites

In addition to the phytolith (in section 3.1), two probable parasite life cycle forms were identified from the sediment sample 27177:24b of grave 1260. The first closely resembled an egg of either roundworm *Ascaris lumbricoides* L, which may infect humans, or *A. suum* Goeze, the type found in swine; these are morphologically indistinguishable (Betson et al., 2014; Søe et al., 2015). The microremain had the undulating membrane (mammilated outer surface, Cruz et al., 2012), thick middle layer, and granular content, typical for *Ascaris* sp. L. (see Fig. 1 and Table 3). Although microscopic examination seldom enables species-level identification, it gives information on the parasite life stage (Cleeland et al., 2013). *Ascaris* sp. L. is a common parasite in humans, and has frequently been identified from ancient settlements, for instance in Viking Age Denmark (1018–1030 AD) (Søe et al., 2015).

The second probable parasite remain resembled an oocyst of a coccidia (see Fig. 1 and Table 3). It is difficult to make an exact identification because the oocyst remains were poorly preserved. The number and morphological characteristics of sporocysts and sporozoites within the oocyst are important characteristics used to distinguish coccidia (Kreier and Baker, 1987). Oocyst size may also aid identification but a reduction in oocyst size over time has been documented in, for example, eimeriid cysts from archaeological samples (Fugassa et al., 2008).

These probable intestinal parasite remains are the first reported from Finnish archaeological samples. Because these were extracted from the intestinal position of a body, it is likely that this population suffered from parasites. The effect of any endoparasite species depends on the nutritional status of the host, but also on possible primary infections with microparasites, bacteria and viruses. Because the parasites found in this study have direct life cycles, i.e. are not dependent on intermediate hosts, they do not directly indicate, for example, dietary preferences, but they may imply poor sanitary conditions.

3.3. Plant fibers

We discovered bast fibers from dental calculus samples of graves 323 and 1260 (See Table 3 and Appendix B). Bast fibers can originate from flax (*Linum usitatissimum* L.) or hemp (*Cannabis sativa* L.), the seeds of which are known from other Iron Age sites (Aalto, 1997; Lempiäinen, 1999, 2011; Núñez and Lempiäinen, 1992), or from nettle (*Urtica dioica* L.), a native species, which can be both eaten or used as textile fiber (Suomela et al., 2017; Vahter, 1953). The fiber in grave 323 was blue in color, indicating a textile source. The other fiber was colorless and can originate either from textile fibers or, if it is nettle, also from food.

Bast fibers are extremely rare and interesting finds, because they were recovered from dental calculus samples, indicating that the calculus helped in preserving them. Some previous studies report plant fibers in calculus, for instance cotton from Danbury, Ohio (900–1000 AD) (Blatt et al., 2011), bast fibers from the Mediterranean Mesolithic (Cristiani et al., 2016, 2018), hemp fibers from Eneolithic or Bronze Age Italy (Sperduti et al., 2018), and plant fibers from Early Medieval Colonna (Gismondi et al., 2018).

3.4. Animal hairs

We extracted a total of 20 animal hair fragments from graves 56, 320, 323, 345, 346, 352, 390 and 1260. These fragments were extracted from dental calculus, from sediment samples that were in contact with metal items, and from the surfaces of ceramic sherds and the bronze cauldron.

The hairs were very short, most were only 0.2–0.6 mm long, and for this reason only some of them could be identified to family or species level. Four fragments were coarse or fine sheep (*Ovis aries* L.) wool, and it is likely that the other mammal hairs were also from sheep. The hairs were white or brown and did not show any signs of dyeing, which might indicate that they were not originally from garments but from the dust that is created during the processing of sheep skin and the production of woolen yarns and textiles.

Additionally, several possible mountain hare (*Lepus timidus* L.) hairs were identified in dental calculus from grave 352, and weasel family (Mustelidae) hairs and four deer family (Cervidae) coarse

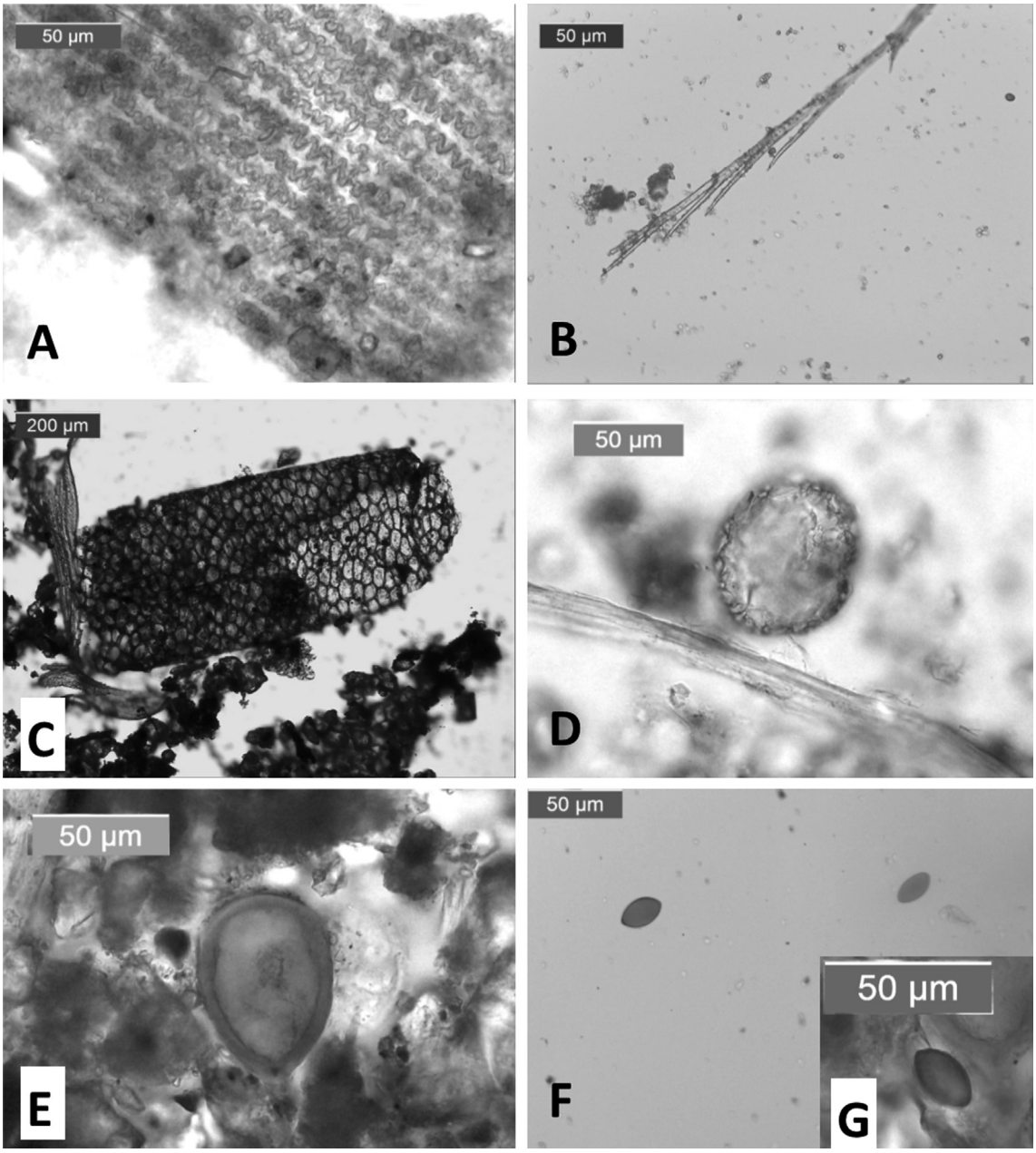

Fig. 1. Microremains recovered from the Luistari cemetery samples. a) Multicell phytolith (27177:24b), b) Feather barbule remain (18000:4426:1b), c) Cervidae sp. hair remain (27177:24b), d) Probable *Ascaris lumbricoides* L./*A. suum* Goeze (27177:24b), e) Probable coccidia (27177:24b), f) Probable fungal spores (18000:3848), g) Probable fungal spore (27177:24b).

hair fragments were found in the sediment sample from grave 1260. Cervidae hairs are common finds from Late Iron Age inhumations, where elk and deer skins were used for covering the deceased (Kirkinen, 2015).. (See Appendix B.)

3.5. Feathers

We identified nine definite bird feather fragments from graves 320, 325, and 390, and two additional possible feather fragments from graves 56 and 323. Three of the feather fragments were extracted from dental calculus samples (graves 320, 323, and 325), one from the surface of a piece of flint (grave 56), and five from an organic residue sample (grave 390). The fragments were 0.14–0.95-mm-long barbules, with hardly any diagnostic features. However, a fragment of a plumulaceous (downy) barbule, in grave 320 calculus sample, was tentatively identified as originating from waterfowl (Anseriformes).

The feather remains from grave 390 may come from a feather-filled pillow, as previously suggested (Kirkinen, 2015).

Three feather fragments in dental calculus samples might have been layered on teeth surfaces for instance through chewing or by inhaling the dusty air when plucking birds. (See Appendix B). Feather fragments have previously been reported from dental calculus samples from Mesolithic Balkans and Early Medieval Italy (Cristiani et al., 2016; Gismondi et al., 2018).

3.6. Other microremains

A single pollen grain, likely from spruce (*Picea abies* (L.) H. Karst), was identified from sediment sample 27177:24b, and

Table 3
List of results. (A) = Possibly Anseriformes. (B) = blue in color.

Catalogue number (NM)	Type of sample							Grass inflorescence phytoliths	*Ascaris lumbricoides* L./*A. suum* Goeze	Coccidia	Fungal spore	Bast fibers	Mammal	*Ovis aries* L.	*Lepus timidus* L.	Mustelidae sp.	Cervidae sp. (coarse hair)	Aves
	Grave	Subsamples (a or b)	Dental calculus	Organic residue	Carbonized residue	Dirt from item surface	Sediment sample											
18000:1644	56			x									1					
18000:1647	56			x									1	2(+1)				
18000:1772	56					x							1					
18000:1774	56					x												1
18000:3627	320	b	x										1					1(A)
18000:3640:4	323		x									1(B)	1					1
18000:3714:17	325		x															1
18000:3846	345				x								1					
18000:3848	345			x							2							
18000:3863	346					x							1					
18000:4013:1	352		x												5			
18000:4426	390			x									1					5
18000:4439:2	390		x															
18000:4443	390					x								1				
27177:24b	1260						x	>30	1	1	1		1	1		1	4	
27717:29c(47)	1260		x									1						

confirmed by Teija Alenius from Department of Cultures, University of Helsinki (personal communication, 12 Dec. 2018). In addition, we recovered possible fungals spores from organic residue sample 18000:3848 and sediment sample (27177:24b).

4. Conclusions

The acidic sediment conditions typical for boreal environments reduce the preservation of organic archaeological remains. Consequently, traditional excavation methods, and osteological and botanical analysis cannot yield a comprehensive overview of the livelihood, culture, and resources of prehistoric people.

We examined the microremains preserved in boreal sediment samples and dental calculus remains from the Luistari cemetery collection. Sixteen of the 66 samples, and nine of the fifteen graves, contained microremains. Microremains were found from both male and female burials, and from all types of samples: dental calculus, organic remains, carbonized remains, item surfaces, and sediments.

Our study demonstrates that systematic microremain sampling of grave sites produced information that may not have been recovered otherwise. We recovered new types of finds, such as intestinal parasites, hare hairs and waterfowl feather remains, that were not represented in previous reports from this site.

Microremains preserved within dental calculus and other samples can give an extraordinary insight to the lifeways of the Iron Age people, their environment, behaviors, or even the presence of particles in the air they breathed (Radini et al., 2017). In cold weather woolen clothes may be considered as a necessity but textiles of plant fiber as luxury goods (Riikonen, 2011), and the microremains in our study record the presence of both. There is some debate whether the textiles were produced locally or acquired through trade (Riikonen, 2011), but bast fibers and animal hair remains in dental calculus suggest fibers and furs were processed by the people themselves.

It is important to recognize that the contents of the alimentary canal can be studied using microremain analysis, even when the body has already decomposed. In this study we demonstrated the opportunities that phytoliths can provide in studying digested food. The parasite egg finds addressed health and hygiene issues.

Although previous work with ancient dental calculus has discovered starch granules (Cristiani et al., 2016; Hardy et al., 2012; Henry and Piperno, 2008; Henry et al., 2011, 2014; Power et al., 2018), our samples did not yield any. We believe that one of the reasons can be the minuscule sizes of the calculus samples. The teeth carried minor deposits of calculus, and we sampled only a fraction of this from each tooth, leaving much for future research. Moreover, acidic sediments of the site may have destroyed starch – the effect of pH on starch preservation has not been fully explored.

In this study we did not have proper control samples from sediments outside the cemetery area, to which the microremains could be compared. In the future, grave research projects should include sampling both onsite materials and offsite controls. In addition, because samples from intestinal and stomach areas have proven to have much potential, it is important to take samples from these areas from all graves, as well as other locations of the burials.

It is likely that graves contain many other plant and animal residues in addition to the types observed here. More proxies should be investigated, such as bedding and decoration material such as mosses, herbs, tree leaves, branches, and animal remains such as fish scales, insect remains, and other microfauna (Cristiani et al., 2016, 2018; Lempiäinen, 2009; Radini et al., 2017; Tranberg, 2018). The potential in microremain studies is endless. Research projects combining macroremain with multiproxy microremain studies can be very successful in obtaining new data on the environment, cultures, and practices of prehistorical people.

Funding

TJ was funded by Kone Foundation [grant number 090063]. AGH was funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program [grant number STG–677576("HARVEST")]. TK was funded by the Academy of Finland[grant number 1278008].

Declarations of interest

None.

Acknowledgements

We would like to thank Antti Lahelma and Johannes Enroth from the University of Helsinki, and Teija Alanko from the University of Turku for support and guidance, and Eija Tuominen, Jouni Heino, and Pirkitta Koponen for assistance and access to the laboratory of Helsinki Institute of Physics, and the employees at the National Board of Antiquities for assistance.

We are thankful to Dan Cabanes for instructing and checking the phytolith analysis results, and (in alphabetical order) Teija Alenius, Heli Etu-Sihvola, Essi Kangasaho, Ulla Moilanen, Tuomas Näreoja, Mirva Pääkkönen, Juha Ruohonen, Kati Salo, Jenni Suomela, Sanna Tuormala, Krista Vajanto, and Santeri Vanhanen for collaboration.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quascirev.2019.105888.

References

Aalto, M., 1997. The cultivated plants of Finnish Iron Age. In: Slavyane I Finno-Ugry: 47–59. Sankt-Peterburg: Dmitriy Bulanin.

Appleyardd, H.M., 1978. Guide to the Identification of Animal Fibres, second ed. Wira, Leeds.

Ball, T., Gardner, J.S., Brotherson, J.D., 1996. Identifying phytoliths produced by the inflorescence bracts of three species of wheat (*Triticum monococcum* L., *T. dicoccon* Schrank., and *T. aestivum* L.) using computer-assisted image and statistical analyses. J. Archaeol. Sci. 23 (4), 619–632. https://doi.org/10.1006/jasc.1996.0058.

Ball, T.B., Gardner, J.S., Anderson, N., 1999. Identifying inflorescence phytoliths from selected species of wheat (*Triticum monococcum, T. dicoccon, T. dicoccoides*, and *T. aestivum*) and barley (*Hordeum vulgare* and *H. spontaneum* (Gramineae). Am. J. Bot. 86 (11), 1615–1623. https://doi.org/10.2307/2656798.

Ball, T.B., Ehlers, R., Standing, M.D., 2009. Review of typologic and morphometric analysis of phytoliths produced by wheat and barley. Breed Sci. 59 (5), 505–512. https://doi.org/10.1270/jsbbs.59.505.

Ball, T.B., Davis, A., Evett, R.R., Ladwig, J.L., Tromp, M., Out, W.A., Portillo, M., 2016. Morphometric analysis of phytoliths: recommendations towards standardization from the international committee for phytolith morphometrics. J. Archaeol. Sci. 68, 106–111. https://doi.org/10.1016/j.jas.2015.03.023.

Betson, M., Nejsum, P., Bendall, R.P., Deb, R.M., Stothard, J.R., 2014. Molecular epidemiology of ascariasis: a global perspective on the transmission dynamics of Ascaris in people and pigs. J. Infect. Dis. 210 (6), 932–941. https://doi.org/10.1093/infdis/jiu193.

Blatt, S.H., Redmond, B.G., Cassman, V., Sciulli, P.W., 2011. Dirty teeth and ancient trade: evidence of cotton fibres in human dental calculus from Late Woodland, Ohio. Int. J. Osteoarchaeol. 21 (6), 669–678. https://doi.org/10.1002/oa.1173.

Bouchet, F., Guidon, N., Dittmar, K., Harter, S., Ferreira, L.F., Chaves, S.M., Reinhard, K., Araújo, A., 2003. Parasite remains in archaeological sites. Memórias do Instituto Oswaldo Cruz 98 (Suppl. 1), 47–52. https://doi.org/10.1590/s0074-02762003000900009.

Brom, Tim, 1991. The Diagnostic and Phylogenetic Significance of Feather Structures. Academisch Proefschrift. Universiteit van Amsterdam, Instituut voor Taxonomische Zoölogie.

Cabanes, D., Burjachs, F., Expósito, I., Rodríguez, A., Allué, E., Euba, I., Vergés, J.M., 2009. Formation processes through archaeobotanical remains: the case of the Bronze Age levels in El Mirador cave, Sierra de Atapuerca, Spain. Quat. Int. 193, 160–173. https://doi.org/10.1016/j.quaint.2007.08.002.

Cabanes, D., Gadot, Y., Cabanes, M., Finkelstein, I., Weiner, S., Shahack-Gross, R., 2012. Human impact around settlement sites: a phytolith and mineralogical study for assessing site boundaries, phytolith preservation, and implications for spatial reconstructions using plant remains. J. Archaeol. Sci. 39, 2697–2705. https://doi.org/10.1016/j.jas.2012.04.008.

Chernova, O.F., 2002. Architectonic and diagnostic significance of hair cuticle. Biol. Bull. 29 (3), 238–247. https://doi.org/10.1023/A:1015482430438.

Cleeland, L.M., Reichard, M.V., Tito, R.Y., Reinhard, K.J., Lewis Jr., C.M., 2013. Clarifying prehistoric parasitism from a complementary morphological and molecular approach. J. Archeol. Sci. 40 (7), 3060–3066. https://doi.org/10.1016/j.jas.2013.03.010.

Cristiani, E., Radini, A., Edinborough, M., Borić, D., 2016. Dental calculus reveals Mesolithic foragers in the Balkans consumed domesticated plant foods. Proc. Natl. Acad. Sci. 113, 10298–10303. https://doi.org/10.1073/pnas.1603477113.

Cristiani, E., Radini, A., Borić, D., Robson, H.K., Caricola, I., Carra, M., Mutri, G., Oxilia, G., Zupancich, A., Šlaus, M., Vujević, D., 2018. Dental calculus and isotopes provide direct evidence of fish and plant consumption in Mesolithic Mediterranean. Sci. Rep. 8, 1–12. Published online. https://www.nature.com/articles/s41598-018-26045-9.pdf.

Crowther, A., Haslam, M., Oakden, N., Walde, D., Mercander, J., 2014. Documenting contamination in ancient starch laboratories. J. Archaeol. Sci. 49, 90–104. https://doi.org/10.1016/j.jas.2014.04.023.

Cruz, L.M., Allanson, M., Kwa, B., Azizan, A., Izurieta, R., 2012. Morphological changes of Ascaris spp. eggs during their development outside the host. J. Parasitol. 98 (1), 63–68. https://doi.org/10.1645/GE-2821.1.

Cummings, L.S., Yost, C., Soltysiak, A., 2018. Plant Microfossils in Human Dental.

Teegen, W.R., Dittmar, K., 2003. The Presence of Fasciola Hepatica (Liver-Fluke) in Humans and Cattle from a 4,500 Year Old Archaeological Site in the Saale-Unstrut Valley, Germany, vol. 98. *Memórias do Instituto Oswaldo Cruz*, Rio de Janeiro, pp. 141–143. Suppl. I. https://doi.org/10.1590/s0074-02762003000900021.

Dolores, R., Piperno, D.R., 1991. The status of phytolith analysis in the American Tropics. J. World PreHistory 5 (2), 155–191.

Dove, Carla, Koch, Sandra, 2010. Microscopy of feathers: a practical guide for Forensic feather identification. JASTEE 1 (1), 15–61.

Fiorin, E., Sáez, L., Malgosa, A., 2019. Ferns as healing plants in medieval Mallorca, Spain? Evidence from human dental calculus. Int. J. Osteoarchaeol. 29, 82–90. https://doi.org/10.1002/oa.2718.

Fugassa, M.H., Sardella, N.H., Taglioretti, V., Reinhard, K.J., Araújo, A., 2008. Eimeriid oocysts from archeological samples in Patagonia, Argentina. J. Parasitol. 94 (6), 1418–1420. https://doi.org/10.1645/GE-1537.1.

García-Granero, J.J., Lancelotti, C., Madella, M., 2015. A tale of multi-proxies: integrating macro- and microbotanical remains to understand subsistence strategies. Veget. Hist. Archaeobot. 24, 121. https://doi.org/10.1007/s00334-014-0486-7.

Gismondi, A., D'Agostino, A., Canuti, L., Di Marco, G., Martínez-Labarga, C., Angle, M., Rickards, O., Canini, A., 2018. Dental calculus reveals diet habits and medicinal plant use in the Early Medieval Italian population of Colonna. J. Archaeol. Sci.: Rep. 20, 556–564. https://doi.org/10.1016/j.jasrep.2018.05.023.

Goodway, M., 1987. Fiber identification in practice. J. Am. Inst. Conserv. 26, 27–44. https://doi.org/10.1179/019713687806027933.

Hald, M.M., Mosekilde, J., Magnussen, B., Søe, M.J., Hansen, C.H., Mortensen, M.F., 2018. Tales from the barrels: results from a multi-proxy analysis of a latrine from Renaissance Copenhagen, Denmark. J. Archaeol. Sci.: Rep. 20, 602–610. https://doi.org/10.1016/j.jasrep.2018.06.006.

Hardy, K., Buckley, S., Collins, M.J., Estalrrich, A., Brothwell, D., Copeland, L., Garcia-Tabernero, A., Garcia-Vargas, S., de la Rasilla, M., Lalueza-Fox, C., Huguet, R., Bastir, M., Santamaria, D., Madella, M., Wilson, J., Cortés, Á.F., Rosas, A., 2012. Neanderthal medics? Evidence for food, cooking, and medicinal plants entrapped in dental calculus. Naturwissenschaften 99, 617–626. https://doi.org/10.1007/s00114-012-0942-0.

Hardy, K., Radini, A., Buckley, S., Sarig, R., Copeland, L., Gopher, A., Barkai, R., 2016. Dental calculus reveals potential respiratory irritants and ingestion of essential plant-based nutrients at Lower Palaeolithic Qesem Cave Israel. Quat. Int., State. multidiscip. res. Middle Pleistocene Qesem Cave, Israel 398, 129–135. https://doi.org/10.1016/j.quaint.2015.04.033.

Henry, A.G., Piperno, D.R., 2008. Using plant microfossils from dental calculus to recover human diet: a case study from Tell al-Raqa'i, Syria. J. Archaeol. Sci. 35 (7), 1943–1950. https://doi.org/10.1016/j.jas.2007.12.005.

Henry, A.G., Brooks, A.S., Piperno, D.R., 2011. Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). Proc. Natl Acad. Sci. U.S.A 108 (2), 486–491. https://doi.org/10.1073/pnas.1016868108.

Henry, A.G., Brooks, A.S., Piperno, D.R., 2014. Plant foods and the dietary ecology of Neanderthals and early modern humans. J. Hum. Evol. 69, 44–54. https://doi.org/10.1016/j.jhevol.2013.12.014.

Kirkinen, T., 2015. The role of wild animals in death rituals: furs and animal skins in the late Iron age inhumation burials in Southeastern Fennoscandia. Fennosc. Archaeol. XXXII, 101–120.

Kirkinen, T., 2017. "Burning pelts": brown bear skins in the Iron age and early medieval (0–1300 AD) burials in south-eastern Fennoscandia. Eesti Arheoloogia Ajakiri 21 (1), 3–29.

Kirkinen, T., 2019. Between Skins: Animal Skins in the Iron Age and Historical Burials in Eastern Fennoscandia. Yliopistopaino, Helsinki.

Kreier, J.P., Baker, J.R., 1987. Parasitic Protozoa. Allen & Unwin, Boston.

Lalueza Fox, C., Juan, J., Albert, R.M., 1996. Phytolith analysis on dental calculus, enamel surface, and burial soil: information about diet and paleoenvironment. Am. J. Phys. Anthropol. 101, 101–113. https://doi.org/10.1002/(SICI)1096-8644(199609)101:1<101::AID-AJPA7>3.0.CO;2-Y.

Larsson, M., 2015. Agrarian Plant Economy at Uppåkra and the Surrounding Area. Archaeobotanical Studies of an Iron Age Regional Center. Acta Archaeological Lundensia, Series in 4°, No. 33. Lund University.
Lehtosalo-Hilander, P.-L., 1982a. Luistari I. The Graves. *Suomen Muinaismuistoyhdistyksen Aikakauskirja 82:1*. Vammalan Kirjapaino Oy, Vammala.
Lehtosalo-Hilander, P.-L., 1982b. Luistari II. The Artefacts. Suomen Muinaismuistoyhdistyksen Aikakauskirja 82:2. Vammalan Kirjapaino Oy, Vammala.
Lehtosalo-Hilander, P.-L., 1982c. Luistari 3: a Burial-Ground Reflecting the Finnish Viking Age Society. In: Suomen Muinaismuistoyhdistyksen Aikakauskirja, 82. Suomen Muinaismuistoyhdistys, Helsinki, 3.
Lehtosalo-Hilander, P.-L., 2000. Luistari IV. A History of Weapons and Ornaments, vol. 107. Suomen Muinaismuistoyhdistyksen Aikakauskirja, Helsinki.
Lehtosalo-Hilander, P.-L., 2001. Euran Puku Ja Muut Muinaisvaatteet. Vammalan Kirjapaino Oy, Vammala.
Lempiäinen, T., 1999. On the history of hemp (Cannabis sativa L.) in Finland and the archaeobotanical evidence. In: Selsing, L., Lillehammer, G. (Eds.), Museumlandskap: Artikkelsamling Til Kerstin Griffin På 60-årsdagen, AmS-Rapport 12A. Arkeologisk museum, Stavanger, pp. 71–78.
Lempiäinen, T., 2002. Plant macrofossils from graves and churches. The archaeobotany of graves from the late Iron age and the middle ages and of medieval churches in Finland and the Karelian Isthmus (Russia). In: Viklund, K. (Ed.), Nordic Archaeobotany – NAG 2000 in Umeå. Archaeology and Environment 15. University of Umeå, pp. 161–172.
Lempiäinen, T., 2005. Ruis rautakauden Suomessa ja Katariinan Kirkkomäen ruisolkipunos. In: Immonen, V., Haimila, M. (Eds.), Mustaa Valkoisella. Ystäväkirja Arkeologian Lehtori Kristiina Korkeakoski-Väisäselle. Dark Oy, Vantaa, pp. 110–119.
Lempiäinen, T., 2009. Havaintoja kasvien jäännöksistä haudoista ja kirkkomailta. In: Pellinen, H.-M. (Ed.), Maasta, Kivestä Ja Hengestä. Markus Hiekkanen Festschrift. Saarijärven Offset Oy, Saarijärvi, pp. 126–135.
Lempiäinen, T., 2011. Notes on the archaeological records of flax (Linum usitatissimum). In: Harjula, J., Helamaa, M., Haarala, J. (Eds.), Times, Things & Places. 36 Essays for Jussi-Pekka Taavitsainen. J.-P. Taavitsainen Festschrift Committee with the Support of Christian Ahlström, Aiha Environments Oy. Benito Casagrande and TS-Yhtymä, Raisio, pp. 192–197.
Lempiäinen, T., Vuorela, I., 1994. Vanhankaupungin maaperäarkiston paleoekologiset tutkimukset. Summary: palaeoecological studies of the soil archive in Old Helsinki. In: Helsinki 1550–1640. Narinkka, Helsinki: Helsingin Kaupunginmuseo, pp. 157–171.
Lempiäinen-Avci, M., Laakso, V., Alenius, T., 2017. Archaeobotanical remains from inhumation graves in Finland, with special emphasis on a 16th century grave at Kappelinmäki, Lappeenranta. J. Archaeol. Sci.: Rep. 13, 132–141. https://doi.org/10.1016/j.jasrep.2017.03.038.
Li, M., Yang, X., Ge, Q., Ren, X., Wan, Z., 2013. Starch grains analysis of stone knives from Changning site, Qinghai Province, Northwest China. J. Archaeol. Sci. 40 (4), 1667–1672. https://doi.org/10.1016/j.jas.2012.11.018.
Madella, M., Alexandre, A., Ball, T., 2005. International code for phytolith nomenclature 1.0. Ann. Bot. 96 (2), 253–260. https://doi.org/10.1093/aob/mci172.
Mariotti Lippi, M., Foggi, B., Aranguren, B., Ronchitelli, A., Revedin, A., 2015. Multistep food plant processing at Grotta Paglicci (Southern Italy) around 32,600 cal B.P. Proc. Natl Acad. Sci. U.S.A 112 (39), 12075–12080. https://doi.org/10.1073/pnas.1505213112.
Namdar, D., Zukerman, A., Aren, M., Maeir, A.M., Citron Katz, J., Cabanes, D., Trueman, C., Shahack-Gross, R., Weiner, S., 2011. The 9th century BCE destruction layer at Tell es-Safi/Gath, Israel: integrating macro- and microarchaeology. J. Archaeol. Sci. 38 (12), 3471–3482. https://doi.org/10.1016/j.jas.2011.08.009.
Núñez, M., Lempiäinen, T., 1992. A late Iron age farming complex from Kastelholms Kungsgård, Sund, Åland Islands. PACT 36, 125–142.
Out, W.A., Ryan, P., García-Granero, J.J., Barastegui, J., Maritan, L., Madella, M., Usai, D., 2016. Plant exploitation in Neolithic Sudan: a review in the light of new data from the cemeteries R12 and Ghaba. Quat. Int. 412, 36–53. https://doi.org/10.1016/j.quaint.2015.12.066.
Pearsall, D.M., 2015. Paleoethnobotany. A Handbook of Procedures, third ed. Left Coast Press, Walnut Creek, California.
Pearsall, D.M., Chandler-Ezell, K., Zeidler, J.A., 2004. Maize in ancient Equador: results of residue analysis of stone tools from the Real Alto site. J. Archaeol. Sci. 31, 423–442. https://doi.org/10.1016/j.jas.2003.09.010.
Perry, L., 2004. Starch analyses reveal the relationship between tool type and function: an example from the Orinoco valley of Venezuela. J. Archaeol. Sci. 31 (8), 1069–1081. https://doi.org/10.1016/j.jas.2004.01.002.
Pichler, S.L., Pümpin, C., Brönnimann, D., Rentzel, P., 2014. Life in the proto-urban style: the identification of parasite eggs in micromorphological thin sections from the Basel-Gasfabrik Late Iron Age settlement, Switzerland. J. Archaeol. Sci. 43, 55–65. https://doi.org/10.1016/j.jas.2013.12.002.
Piperno, D.R., 1988. Phytolith Analysis. An Archaeological and Geological Perspective. Academic Press, San Diego.
Piperno, D.R., 2006. Phytoliths. A Comprehensive Guide for Archaeologists and Paleoecologists. AltaMira Press, Lanham, MD.
Portillo, M., Ball, T., Manwaring, J., 2006. Morphometric analysis of inflorescence phytoliths produced by *Avena sativa* L. and *Avena strigosa* Schreb. Econ. Bot. 60 (2), 121–129. https://doi.org/10.1663/0013-0001(2006)60[121:MAOIPP]2.0.CO;2.
Power, R.C., Salazar-García, D.C., Rubini, M., Darlas, A., Havarti, K., Walker, M., Hublin, J.-J., Henry, A.G., 2018. Dental calculus indicates widespread plant use within the stable Neanderthal dietary niche. J. Hum. Evol. 119, 27–41. https://doi.org/10.1016/j.jhevol.2018.02.009.
Radini, A., Nikita, E., Buckley, S., Copeland, L., Hardy, K., 2017. Beyond food: the multiple pathways for inclusion of materials into ancient dental calculus. Am. J. Phys. Anthropol. 162, 71–83. https://doi.org/10.1002/ajpa.23147.
Radini, A., Tromp, M., Beach, A., Tong, E., Speller, C., McCormick, M., Dudgeon, J.V., Collins, M.J., Rühli, F., Kröger, R., Warinner, C., 2019. Medieval women's early involvement in manuscript production suggested by lapis lazuli identification in dental calculus. Sci. Adv. 5 eaau7126. https://doi.org/10.1126/sciadv.aau7126.
Rast-Eicher, A., 2016. Fibres. Microscopy of Archaeological Textiles and Furs. Archaeolingua, Budabest.
Reinhard, K.J., 1992. Parasitology as an interpretive tool in archaeology. Am. Antiq. 57 (2), 231–245. https://doi.org/10.2307/280729.
Riikonen, J., 2011. White linen - cloth of luxury.). In: Harjula, J., Helamaa, M., Haarala, J. (Eds.), Times, Things & Places. 36 Essays for Jussi-Pekka Taavitsainen. J.-P. Taavitsainen Festschrift Committee with the Support of Christian Ahlström, Aiha Environments Oy. Benito Casagrande and TS-Yhtymä, Raisio, pp. 199–221.
Rosen, A.M., 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach. In: Rapp, G.J., Mulholland, S.C. (Eds.), Phytolith Systematics: Emerging Issues: Advances in Archaeological and Museum Science 1. Plenum, New York, pp. 129–147.
Salo, Kati, 2005. What Ancient Human Teeth Can Reveal? Demography, Health, Nutrition and Biological Relations in Luistari. University of Helsinki.
Søe, M.J., Nejsum, P., Fredensborg, B.L., Kapel, C.M.O., 2015. DNA typing of ancient.
Søe, M.J., Nejsum, P., Seersholm, F., Fredensborg, B.L., Habraken, R., Haase, K., Hald, M.M., Simonsen, R., Højlund, F., Blanke, L., Merkyte, I., Willerslev, E., Kapel, C.M.O., 2018. Ancient DNA from latrines in Northern Europe and the Middle East (500 BC–1700 AD) reveals past parasites and diet. PLoS One 13 (4), 1–17 e0195481. https://doi.org/10.1371/journal.pone.0195481.
Sperduti, A., Giuliani, M.R., Guida, G., Petrone, P.P., Rossi, P.F., Vaccaro, S., Frayer, D.W., Bondioli, L., 2018. Tooth grooves, occlusal striations, dental calculus, and evidence for fiber processing in an Italian eneolithic/bronze age cemetery. Am. J. Phys. Anthropol. 167, 234–243. https://doi.org/10.1002/ajpa.23619.
Suomela, J., Vajanto, K., Räisänen, R., 2017. Seeking nettle textiles – utilizing a combination of microscopic methods for fibre identification. Stud. Conserv. 63 (7), 412–422. https://doi.org/10.1080/00393630.2017.1410956.
Teerink, B., 2003. Hair of West-European Mammals: Atlas and Identification Key. Cambridge University Press, Cambridge.
Tranberg, A., 2018. Ympäristön Ja Ihmisen Suhteen Muuttuminen Perämeren Rannikolla Varhaismodernina Aikana: Makrofossiilitutkimus Kasvien Käytöstä Muuttuvassa Maailmassa. University of Oulu.
Tridico, S., 2005. Examination, analysis, and application of hair in forensic science — animal hair. Forensic Sci. Rev. 17 (1), 18–28.
Tromp, M., Buckley, H., Geber, J., Matisoo-Smith, E., 2017. EDTA decalcification of dental calculus as an alternate means of microparticle extraction from archaeological samples. J. Archaeol. Sci.: Rep. 14, 461–466. https://doi.org/10.1016/j.jasrep.2017.06.035.
Vahter, T., 1953. Obinugrilaisten kansojen koristekuosit: Ornamentik der Ob-Ugrier. Suomalais-ugrilainen seura 1953, Helsinki.
Vanhanen, S., 2012. Archaeobotanical study of a late Iron age agricultural complex at Orijärvi, eastern Finland. Fennosc. Archaeol. XXIX, 55–72.
Vuorela, I., 1994a. 1600-luvulla hylätty kaivo. Summary: well abandoned in the 17th century. In: Helsinki 1550–1640. Narinkka 1994. Helsinki: Helsingin Kaupunginmuseo, pp. 182–197.
Vuorela, I., 1994b. Palynological investigations in the old town of Helsinki. Bull. Geol. Soc. Finl. 66 (2), 125–128.
Vuorela, I., 1999. Mikrofossiilit asutushistorian indikaattoreina. *Geologi* 51 (8), 127–132.
Vuorela, I., 2003. Siitepöly- ja fytoliittianalyysit osana kaupungin asutushistorian tutkimusta. Summary: pollen and phytolith analysis in the study of Turku's settlement history. In: Seppänen, L. (Ed.), Kaupunkia Pintaa Syvemmältä: Arkeologisia Näkökulmia Turun Historiaan. Archaeologia Medii Aevi Finlandiae 9. TS-Yhtymä: Suomen Keskiajan Arkeologinen Seura, Turku, pp. 341–350.
Vuorela, I., Lempiäinen, T., 1993. Palynological and palaeobotanical investigations in the area of the post-medieval Helsinki old town. Veg. Hist. Archaeobotany 2, 101–123. https://doi.org/10.1007/BF00202187.
Vuorela, I., Grönlund, T., Lempiäinen, T., 1996. A reconstruction of the environment of Rettig in the city of Turku, Finland on the basis of diatom, pollen, plant macrofossil and phytolith analyses. Bull. Geol. Soc. Finl. 68 (2), 46–71.
Warinner, C., Rodrigues, J.F., Vyas, R., Trachsel, C., Shved, N., Grossmann, J., Radini, A., Hancock, Y., Tito, R.Y., Fiddyment, S., Speller, C., Hendy, J., Charlton, S., Luder, H.U., Salazar-Garcia, D.C., Eppler, E., Seiler, R., Hansen, L.H., Castruita, J.A., Barkow-Oesterreicher, S., Teoh, K.Y., Kelstrup, C.D., Olsen, J.V., Nanni, P., Kawai, T., Willerslev, E., von Mering, C., Lewis Jr., C.M., Collins, M.J., Gilbert, M.T., Ruhli, F., Cappellini, E., 2014. Pathogens and host immunity in the ancient human oral cavity. Nat. Genet. 46 (4), 336–344.
Zarrillo, S., Pearsall, D.M., Raymond, J.S., Tisdale, M.A., Quon, D.J., 2008. Directly dated starch residues document early formative maize (Zea mays L.) in tropical Ecuador. Proc. Natl Acad. Sci. U.S.A 105 (13), 5006–5011. https://doi.org/10.1073/pnas.0800894105.